

REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-02-

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0212

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE	3. REPORT TYPE AND DATES COVERED 01 APR 2001 - 30 NOV 2001	
4. TITLE AND SUBTITLE SIAM Conference on Control and Its Applications			5. FUNDING NUMBERS F49620-01-1-0250	
6. AUTHOR(S) Anthony Bloch, William Hager				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Society for Industrial and Applied Mathematics 3600 University City Science Center Philadelphia, PA 19104-2688			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFOSR/NM 801 N. Randolph Street Room 732 Arlington, VA 22203-1977			10. SPONSORING/MONITORING AGENCY REPORT NUMBER F49620-01-1-0250	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED			12b. DISTRIBUTION CODE NOTICE OF AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (AFOSR) HAS BEEN REVIEWED AND IS APPROVED FOR PUBLIC RELEASE LAW AFR 100-12. DISTRIBUTION IS UNLIMITED.	
13. ABSTRACT (Maximum 200 words) The SIAM Activity Group on Control and Systems Theory joined forces with the SIAM Annual Meeting in hosting the Fifth SIAM Conference on Control and Its Applications in San Diego. Short courses on Flow Control by Max Grunzburger and on Shape Optimization by Michel Delfour preceded the conference, setting the stage for a program that included 84 minisymposia and 13 invited presentations. 86% of the attendees were from academia, 9% industry, 5% government. Attendees included 30 states within the united states and 20 countries abroad.				
14. SUBJECT TERMS			15. NUMBER OF PAGES 4	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT	

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Final Technical Report

Fifth SIAM Conference on Control and Its Applications
July 11 - 14, 2001
Town & Country Hotel, San Diego, CA

The SIAM Activity Group on Control and Systems Theory joined forces with the SIAM Annual Meeting in hosting the Fifth SIAM Conference on Control and Its Applications in San Diego. Short courses on Flow Control by Max Gunzburger and on Shape Optimization by Michel Delfour preceded the conference, setting the stage for a program that included 84 minisymposia and 13 invited presentations. 86% of the attendees were from academia, 9% industry, 5% government. Attendees included 30 states within the united states and 20 countries abroad.

The conference literally kicked off with a plenary talk by Raffaello D'Andrea on cooperative control, a field dealing with the control of entities that exchange information while working towards an overall group objective. Highlights of the talk were video clips of Cornell's world championship robotics soccer victories in 1999 (Stockholm) and 2000 (Melbourne). D'Andrea attributed their RoboCup victories to the incorporation of optimal control techniques in their team strategies.

In the first joint session with the annual meeting, Jerry Marsden explained the role of celestial dynamics in trajectory design for space missions, focusing on the role of three and four body problems. The theory was illustrated in the context of the upcoming Genesis mission which collects solar wind samples and brings them to earth. Invariant manifolds, periodic orbits, and the equilibrium points of the three body problem were introduced, and saddle point controllers for remaining on the so-called halo orbit were described.

In the second joint session, P. Kumar examined wireless communication networks. In the wireless environment, packets can be relayed from node to node. When a node broadcasts its own information, it can also interfere with the broadcasts of other nodes. One of many observations of Kumar might be paraphrased in the following way: the most information is passed through the network when the broadcast range of each node is as small as possible without disconnecting the network. Gilbert Strang, in the address of the outgoing president, also sought to unify the annual meeting with the control conference by providing a linear algebra view of the well-known Kalman filter, observing that Kalman's filter was essentially a statement about tridiagonal matrices and their factorization.

Two prizes were given at the conference. First, the W. T. and Idalia Reid Prize in Mathematics was given to Eduardo Sontag in honor of his contributions to nonlinear control theory. In his talk following the prize presentation, Sontag examined "Feedback Control Theory and the Challenges of Postgenomic Molecular Biology." Now that the genomes of many species are substantially mapped, and the structure of the encoded proteins are being solved for, the next step is to develop a "systems molecular biology" to characterize the behavior of complete cellular signal pathways. The scientific and medical payoff of such knowledge will literally change our understanding of life and result in revolutionary therapies. A major effort involving the biology, computer science, chemistry, and physics communities is under way in this direction, and Sontag discussed

in his lecture the potential role to be played by concepts and techniques from feedback control theory.

The second prize, awarded by the control activity group to a younger researcher, was given to Vincent Blondel for his research at the interface between system theory and computational complexity theory. His work on the computational complexity of problems ranging from the robust stability of time-varying linear systems to controllability of hybrid systems to stability of saturated linear systems addressed fundamental problems in systems and control theory from a novel point of view, delineating the limitations of mathematical analysis and computation in certain contexts. As an illustration in his talk, he observed that easy to state problems concerning the growth of products of matrices or the decay of solutions of dynamical systems were undecidable. That is, there is no algorithm that always halts with the right answer.

Although optimal control emerged initially in the context of differential equations, applications soon advanced to partial differential equations including the pioneering work of J. L. Lions on a variety of topics ranging from impulse control to decomposition methods. Lions, who passed away recently, was remembered by Tom Banks before the Reid Prize lecture was given. The short courses on flow control and shape optimization at the start of the conference were followed by a series of related minisymposia. As one might expect, flow control involves the application of optimal and feedback control in the design of optimal flows around objects. The minisymposia approached this field via numerical methods (reduction of these high dimensional complex problems to lower dimensions using reduced order models or proper orthogonal decompositions) and a rich variety of applications from chemical vapor deposition to air flow around a wing.

The plenary talk of Olivier Pironneau provided a survey of the huge, growing, and difficult field of shape optimization. Applications are pervasive, from structural design problems (design a bridge in order to maximize the minimal wind velocity that causes oscillation), to the design of ship hulls to minimize drag, to the design of low weight solar collectors for satellites.

Another research direction in PDE control showcased at the conference concerns the control of interactive structures. These structures, surveyed in the plenary lecture of Irena Lasiecka, are described by systems of PDEs with coupling terms on interfaces. For example, the equations of elasticity might be coupled at the boundary (interface) with the plate or shell equation, a typical configuration in structural acoustic control problems with smart actuators and sensors. One may also consider additional coupling with the heat equation in describing a thermoelastic system whose elastic properties are modified by heating effects. These couplings lead to a new class of control models with a strong mixture of hyperbolic and parabolic characteristics. New theory exploiting propagation of hyperbolicity and smoothing effects due to parabolicity were used to describe stabilization and controllability properties.

John Betts, an aerospace engineer from Boeing, provided an industrial facet to the conference. Betts discussed practical issues that arise when trying to solve control problems with "black box" dynamics. That is, in industrial applications, the equations that model a physical process may be quite complicated. The engineer is given, in essence, a black box describing the system, which must be controlled or optimized. Numerical issues in optimal control were highlighted in the talks of Assen Dontchev and Fredi Tröltzsch from both the ODE and PDE viewpoint. Dontchev focused on the role of

solution regularity and Lipschitzian stability in the derivation of error estimates for discretizations, using splines and state constrained problems for illustrations. Troeltzsch noted that certain embeddings, valid in 1 dimension, break down in higher dimensions, leading to a more complicated analysis involving bootstrapping arguments. Troeltzsch's talk concluded with a movie (the North American premier) of an optimally cooled steel beam.

A talk with a strong applied component, given by Ralph Smith, explained how hysteresis and inherent nonlinearities can be accommodated in the design of systems which utilize smart materials. The atomic force microscope, an instrument requiring nanoscale precision, was used as a motivating application. Smith pointed out the crucial importance of collaboration between mathematicians and engineers in the development of effective control strategies that are backed up by rigorous mathematical theory.

Another facet of the conference addressed algebra and operator theoretical issues, culminating in the invited address of William Helton on matrix inequalities and computer assisted analysis. In his talk he showed how matrix inequalities arise and he sketched recent developments of symbolic methods for automatically determining if a given function of matrices is "matrix convex." Helton's talk concluded with the following short summary of the conference: "it was fun."

The plenary talks were indeed a high point of this conference. The presentations provide a forum for the dissemination of the latest research findings in the broad field of control.

A summary of the topics were:

IP1 Cooperative Control: Case Studies
Raffaello D'Andrea, Cornell University

IP2 Solving Optimal Control Problems-A Practical Perspective John T. Betts, The Boeing Company

JP1 Dynamical Systems and Control in Celestial Mechanics and Space Mission Design
Jerrold E. Marsden, California Institute of Technology

IP3 Applied Optimal Shape Design
Olivier Pironneau, Universite Paris VI, France

IP4 Quantum Measurement and Feedback
Hideo Mabuchi, California Institute of Technology, USA

JP2 Pervasive Wireless Networks: Some System Theoretic Challenges P. R. Kumar, University of Illinois, Urbana-Champaign

IP5 Recent Progress in Control and Stabilization of Coupled PDE's Systems Arising in "Smart" Material's Technology
Irena Lasiecka, University of Virginia.

IP6 Approximations in Constrained Optimal Control
Assen Dontchev, Mathematical Reviews (AMS) and the University of Michigan, Ann Arbor

IP7 Optimal Control of Partial Differential Equations, Numerical Analysis and Applications

Fredi Troltzsch, Technische Universitaet Berlin, Germany

IP8 Matrix Inequalities and Analyzing Them Automatically J W. Helton, University of California, San Diego

IP9 Model Development and Control Design for High Performance Nonlinear Smart Material Systems

Ralph C. Smith, North Carolina State University

Respectfully submitted,

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